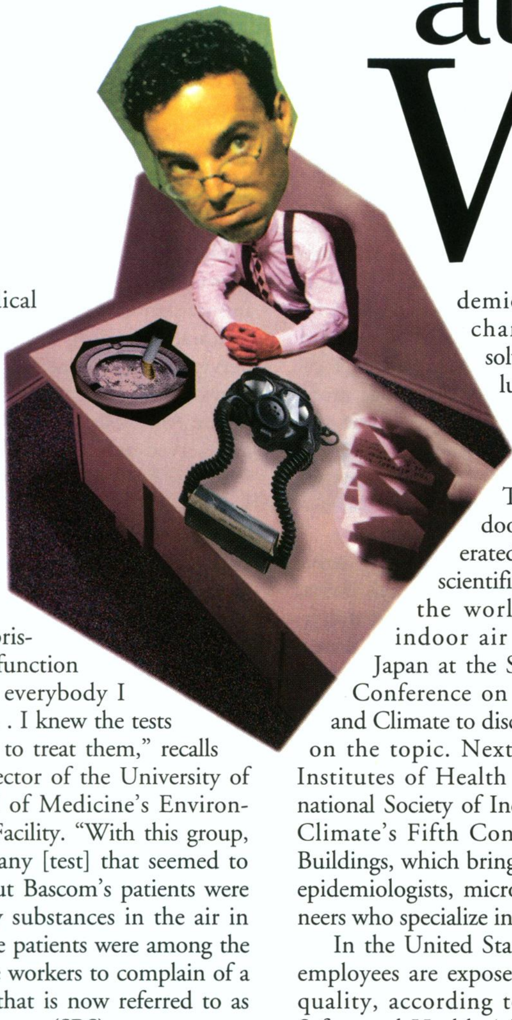
Sick Days at Work



Early in her medical career, Rebecca Bascom became puzzled by a stream of patients complaining of respiratory problems. Bascom, a pulmonary specialist, ran standard lung tests on these patients, whose lungs, surprisingly, seemed to function normally. "With everybody I had seen before . . . I knew the tests to order, the way to treat them," recalls Bascom, now director of the University of Maryland School of Medicine's Environmental Research Facility. "With this group, there just wasn't any [test] that seemed to work." It turns out Bascom's patients were being made ill by substances in the air in their offices. These patients were among the first wave of office workers to complain of a set of symptoms that is now referred to as sick building syndrome (SBS).

According to the World Health Organization, up to 30% of new and remodeled buildings worldwide contain enough pollutants to make workers ill. Asbestos, radon, and environmental tobacco smoke can cause lung cancer or chronic pulmonary disease. And pollutants like volatile organic compounds (VOCs) and bioaerosols—airborne particles emitted by fungi and bacteria—may be causing equally hazardous, though less well-understood, illnesses. Scientists have identified more than 1,500 indoor air pollutants from sources such as carpets, photocopiers, and ventilation ducts.

Researchers suggest that symptoms of SBS result from a complex, hard-to-study blend of pollutants that affects individuals differently. In response, scientists are wielding a range of research tools—from epidemiology studies to air chamber studies—to solve the indoor air pollution problem.

A Growing Concern

The problem of indoor pollution has generated concern among the scientific community around the world. This past July, indoor air researchers met in Japan at the Seventh International Conference on Indoor Air Quality and Climate to discuss the latest research on the topic. Next year, the National Institutes of Health will host the International Society of Indoor Air Quality and Climate's Fifth Conference on Healthy Buildings, which brings together physicians, epidemiologists, microbiologists, and engineers who specialize in indoor air quality.

In the United States, up to 21 million employees are exposed to poor indoor air quality, according to the Occupational Safety and Health Administration. Several major office buildings have recently made headlines by being diagnosed as "sick." At a New York office used by Memorial Sloan-Kettering Cancer Center, environmental investigators found high levels of carbon monoxide that forced more than 700 workers into temporary quarters. At Boston's Suffolk County Courthouse, a fume-emitting waterproofing compound caused over 800 employees to move to makeshift offices elsewhere. And in Washington, D.C., health investigators discovered toxic fungi and poor ventilation in the Department of Transportation's headquarters. Again, workers had to evacuate.

Jim Young, a spokesperson for the New York Committee for Occupational Safety and Health (NYCOSH), a nonprofit advocacy group for workers, says he receives about 300 telephone calls a month from workers worried about their health. The majority of these calls, he says, involve indoor pollutants. "Indoor air quality is probably the most prevalent occupational health problem that we hear about," Young says. "There have just been more and more calls over time."

Researchers trace a rise in indoor air pollution to the 1970s when the energy crisis dictated a cut in air-handling costs. In 1973, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) reduced the professional standard for the minimum amount of outdoor air brought into buildings by 70%. In the past, office employees had received 20–30 cubic feet of outdoor air per minute per person (cfm/p). The 1973 recommendation called for heating, ventilation, and air-conditioning (HVAC) systems to provide a minimum of just 5 cfm/p of outdoor air.

This outdoor air cutback accompanied a gradual rise in the use of photocopiers, laser printers, personal computers, and other equipment that may release chemical fumes. What's more, architectural designs changed and sealed windows, wall-to-wall carpeting, and fiberglass or particle board materials that may also contribute to the problem were increasingly used in buildings.

Researchers say that lower ventilation rates combined with increased exposure to indoor pollutants might explain the rash of SBS-type illnesses. According to the EPA, most Americans spend up to 90% of their time indoors, whether at the office or home. The EPA also suggests many indoor pollutants are concentrated at levels 2–5 times higher than outdoor levels. Other researchers suggest that psychological factors associated with the work environment including monotonization, loss of privacy, electronic monitoring of productivity, a faster work pace, and bad management practices may also play a role by increasing worker stress and compounding awareness of symptoms.

Too Little Data

Still, despite the statistics and plausible explanations, studies of hazardous buildings suffer from a lack of data as well as disagreements over sampling techniques, exposure assessments, and nomenclature. "Think of it this way," says John Spengler, a professor of environmental science and physiology at Harvard University, "when you're doing classic epidemiology, you may have to control a lot of variables, but you're still just making observations about individuals or groups of individuals. When you talk about buildings, you expand the inherent variability. You have to consider stress, job dissatisfaction, vibration, noise, lighting. There are so many factors that it's much more difficult to study. So there has yet to be a 1,000-building study."

Understanding and fixing indoor air pollution problems hasn't been as easy as researchers hoped. "Ten years ago, as epidemiologists we anticipated that we would figure out the causes [of SBS] by studying the atmosphere in buildings and diagnosing the probability [of illness] by knowing what's in the air," remarks Michael Hodgson, an associate professor of occupational and environmental medicine at the University of Connecticut. "But that has not worked because of limitations in our study designs, sampling frames, and exposure assessment strategies." Simply increasing ventilation rates, for example, hasn't solved the problem in every instance, although studies show that symptoms do improve when rates are increased from the current professional design standard of 25 cfm/p of outdoor air to 50cfm/p. In 1990, ASHRAE modified its ventilation guidelines, recommending that building owners return outdoor air flow rates to around 20 cfm/p. Still, indoor air pollution complaints continue.

Ongoing uncertainty leaves builders and engineers without any indoor air regulatory standards to follow, notes Hillel Koren, director of the human studies division at the EPA's National Health and Environmental Effects Research Laboratory. "It would be very difficult, at this point, to create [regulatory standards]," Koren says. "In outdoor pollutants, like ozone, there are ambient national quality standards and a scientific database. In indoor air, we are at an early stage of establishing, characterizing, and developing good biomarkers and endpoints. Here, we are just getting started." Still, Hodgson argues that regulatory standards have always lagged behind good professional standards and that adoption of the ASHRAE standard would solve a lot of the health complaints.

A Volatile Situation

At first, Mary Ann Mazzella, an administrative aide at New York University, began suffering from headaches. Then she began to have sinus problems. Soon she noticed she was feeling lethargic. Eventually, on hot days, she got so nauseous at the office that she'd call it quits and head home early. "I never got to the point where I was seriously ill," says Mazzella, "but I felt terrible."

With help from her local union, Mazzella got her office building's blueprints and surmised the source of her misery: industrial fumes and poor ventilation. "I work in a renovated factory building," Mazzella says. "We're supposed to have fresh air ducts every few feet. We don't. We have no windows. And the air conditioning shuts down for days at a time."

In fact, the photocopying room in Mazzella's building lacked a filtering system to flush out air rich in VOCs, including formaldehyde and ozone, which are emitted by photocopiers. This is a common oversight, according to indoor air researchers. Reporting in the July 1995 issue of the *ASHRAE Journal*, Hodgson and colleagues noted that, "In our experience, complaints around photocopiers abound, presumably because of ventilation inadequate for the needs imposed by this particular source."

Something in the Indoor Air

Volatile organic compounds
- Alkanes
- Aromatic hydrocarbons
- Esters
- Alcohols
- Aldehydes
- Ketones

Sources
- Solvents and cleaning compounds
- Glues and resins
- Spray propellants
- Fabric and furnishings
- Waxes and polishes
- Building materials
- Stored gasoline
- Drycleaning fluids
- Paints

Biologic organisms
- Fungal spores
- Bacteria
- Viruses
- Pollens
- Arthropods
- Protozoa

Sources
- Mold, mildew, and other fungi
- Humidifiers with stagnant water
- Water-damaged surfaces and materials
- Condensing coils and drip pans in HVAC systems
- Some thermophilics on dirty heating coils
- Animals, rodents, insects, and humans

Source: Samet JM and Spengler JD, eds. Indoor Air Pollution: A health perspective. Baltimore: Johns Hopkins University Press, 1991.

In addition to photocopiers, a variety of building equipment and materials including paint, cleaning compounds, glues, silicone caulking material, insecticides, laser printers, personal computers, photographic equipment, fiberglass, and carpeting can give off irritating chemicals. Like Mazzella, employees affected by this chemical soup report a number of allergy-like symptoms.

Researchers often classify VOC sources based on how fast their emissions decline. For example, solid, dry materials like carpet or particle board are "slow decay" sources, meaning they strike the air with an initial blast of chemicals, then emissions slowly fall. Wet products like paints, adhesives, or waxes are "fast decay" sources that release most of their chemicals within minutes to days, though VOCs may be emitted for months or even years.

One wet product to gain attention in recent years is the adhesive glue used to install some carpets. Such glue can infuse the air with VOCs such as formaldehyde. Because of these chemicals, manufacturers recommend that new carpet owners temporarily turn up their ventilation systems.

Some workers may be more susceptible to VOC emissions than others. A myriad of factors ranging from noise to harsh lighting can aggravate symptoms of illness, making employees more aware of their physiological reactions. Awareness of an unusual odor, such as one emanating from carpeting, for example, can even make employees suspicious of air quality that is actually acceptable. "Smell plays a role because people smell things they don't expect to and [believe] there must be something wrong," explains William Cain, a professor of surgery and head of the Chemosensory Perception Laboratory at the University of California at San Diego. "They think that if something smells bad, it may be bad for you. That really isn't a good toxicological rule."

Cain is conducting experiments to separate the psychological effects of odor from measurable nasal inflammation and eye irritation, which more accurately pinpoint building-induced health problems. In a recent study to be published in *Perception and Psychophysics*, Cain and colleagues administered mixtures of VOCs to two sets of people: those with a normal sense of smell, and anosmics, or those without a sense of smell. In both groups of people, the researchers established threshold levels of physiological irritation for mixtures of chemicals like ethyl acetate, butanol, and benzene. "Every organic compound has an odor threshold and an irritation threshold," says Cain. "At some point above these thresholds, people can sense irritation. Our work entails measuring the difference. We use people without a sense of smell to measure the point where things truly become irritating."

So far, Cain and colleagues have found that the more chemical compounds that are combined, the more likely they are to cause physiological reactions. "If you want to be rash, you might say we get increasing additivity [more reactions between chemicals] with increasing complexity. You may have nine components in a study, and the real environment has 100 components. By the time you get to 100, you really have a tremendously more potent stimulus than you would predict by just knowing the individual components involved."

The additivity of VOCs may have foiled many attempts to discern toxic levels of chemicals in a building. Traditionally, environmental investigators simply measured the levels of individual airborne chemicals. But this approach overlooks the interaction between those chemicals. "The whole theory since the 1930s has operated on a flawed philosophy that maximum allowable concentrations were the best way [to measure indoor pollutants]," says Hodgson. "That helps explain why people have symptoms even while [equipment] perceives low levels."

Unfortunately, Cain says, research into VOC interaction is technical and expensive. "The problem is that we've got hundreds of chemicals. If we're going to talk about health effects that we're interested in, we've got to begin building the database one chemical at a time. Looking at the task, it seems almost insurmountable. But it's the tried-and-true path."

Koren is one researcher willing to travel that path. He and his colleagues are conducting a number of chamber studies in which they expose subjects to controlled amounts of VOCs. Using nasal wash to measure a subject's reactions and ocular examinations, the scientists can look for objective biological changes that indicate inflammation. "Our procedures allow us to measure changes that would lead to irritation and congestion, which are some of the most prominent complaints of SBS," Koren says.

Rather than build a database one chemical at a time, Koren hopes to find a model or prototype of VOCs to represent whole families of compounds with similar structures. "Ideally, once we find some clinical endpoints, I'd like to work with epidemiologists who can identify sick buildings, engineers to monitor exposure, . . . biologists of various disciplines that can analyze whatever we find," Koren says. "It's got to be the kind of research that can integrate studies."

Invisible Zoo

Abundant as they may be, VOCs are not the only hazards to inhabit office air. Fungi, bacteria, viruses, algae, and other microbes lurk inside air ducts, grow around ceiling tiles, and thrive on almost any warm, damp surface.

Treadmill testing. Environmentally controlled chambers are used to monitor exposure to indoor air pollutants.

Microbes need only four basic ingredients to survive: organic nutrients on which to feed, moisture (whether from humid air or standing water), a surface on which to grow, and darkness. Fungi usually travel from outdoors into a building, so high concentrations of mold or fungi occur in buildings surrounded by trees or shrubs. Once the microbes get inside, they capitalize on the nourishing environment of indoor humidity, dust, and dirt.

While their living requirements are minimal, microbes' health effects are quite substantial. Bacteria and fungi can produce airborne particles called bioaerosols, such as spores or mycotoxins. These bioaerosols can leave employees with symptoms such as coughing, headaches, and other allergic reactions. Buildings left vacant or recently renovated are particularly susceptible to microbe invasions. Researchers suggest that renovating a building may increase the concentration of indoor air contaminants 1,000-fold.

Like VOCs, microbial contamination can be difficult to assess and treat. Current microbiological techniques are very limited, says Mark Mendell, an epidemiologist with the Cincinnati office of the National Institute for Occupational Safety and Health. "For one thing," he says, "conventional measurements typically only measure organisms that will actually grow on culture, but it is not only the living organisms that can cause problems. Nonliving spores, or pieces of organisms, or substances released from organisms can all have health effects, either allergic or toxic. For example, there are substances called mycotoxins (released from fungi) and endotoxins (contained in gram-negative bacteria) that are known to have serious adverse health effects at high levels in agricultural environments. A variety of evidence now suggests that both of these may be causing health effects at high levels in some indoor environments as well, but these substances are not usually measured indoors."

Koren and others are trying to identify what makes a person susceptible to irritation from biological contaminants. Koren's microbe research includes buildings and homes, both of which can host high levels of fungi and other microbes. Koren is studying interactions between outdoor and indoor pollutants. "Our question is, does exposure to outdoor pollutants like ozone increase a person's sensitivity to [indoor pollutants] like dust mites," Koren says. "We hope to help other agencies come up with prevention policies that take into account how the indoor environment fits with the outdoor environment."

In one experiment, Koren and colleagues exposed asthmatic study participants sensitive to dust mites to ozone and later to allergens carried by dust mites found in homes. Results appear to show that the combined contaminants spur a much stronger asthmatic reaction than either does alone.

Filling in the Gaps

Because little data exists on VOCs, microbes, and other indoor pollutants, researchers are furiously working to fill in the gaps. For example, the EPA's Indoor Air Division is about halfway through a study of 100 randomly-chosen office buildings across the United States with the goal of creating basic pollution data on typical buildings.

"There isn't a lot of information about the quality of air in office buildings now," explains Susan Womble, an EPA environmental scientist and manager of the project, called Baseline Information on Indoor Air Quality in Large Buildings, or BASE. "So when people investigate sick building syndrome, for example, they don't have anything to compare their measurements to."

With the help of 40 experts, the EPA developed a standardized protocol—including characterization of a building, environmental monitoring, and questionnaires on health symptoms—with which to inspect buildings. Scientists have now studied 41 buildings. Information on the first 13 became available to researchers this fall. "We expect to use the data for trends and to help us spot indicators that we should be following up on," Womble says. "We're hoping that this will also give us some insight into other studies that we need to target."

Meanwhile, James Woods, an environmental design professor and director of the Center for Building Health, Safety, and Productivity at Virginia Polytechnic Institute and State University, is working on a different approach: communication between practitioners. Because indoor air pollution spans many fields, epidemiology, microbiology, occupational medicine, and engineering specialists often find themselves working at cross purposes. Woods explains, "A clinician is going to approach the problem from the patient's perspective. A public health person is going to look at preventive measures. Engineers look at specific buildings. Policy makers look at sets of buildings. We want to try to get that all together and be able to address problems."

To bring indoor air specialists together, Woods and colleagues are planning a 1997 meeting, Healthy Buildings: Global Issues and Regional Solutions. The conference will be hosted by the NIH in conjunction with ASHRAE's annual conference. Eventually, Woods hopes to establish standardized methods of defining, tracking, and treating buildings that, over time, experience varying rates of pollution.

"I think awareness [of building pollution] is changing," Woods says. "So the social trend is greater demand for improved performance of buildings. That includes thermal conditions, lighting, acoustic, and ergonomic factors." Woods notes that such factors affect employee stress, which in turn aggravates most health symptoms. "If you address just one of these factors, the level of stress is not affected well enough. You've got to address all of them."

While these researchers attempt to refine existing approaches, others are examining often overlooked pollutants. At Cornell University, Alan Hedge, a professor of design and environmental analysis, blames some indoor health complaints on manmade mineral fibers dropped into the air by ceiling tiles, insulation, and ventilation systems. In a recent study, Hedge and colleagues discovered high rates of employee health complaints correlated with high numbers of manmade mineral fibers in settled dust. In another study, after installing filter systems that collected the fibers, Hedge says, the number of complaints plummeted.

Hedge stumbled across the mineral fiber phenomenon while investigating a building for VOC contamination. "We were inside the building when one employee said to me 'I'm sure there's something in this building. I've got an air filter on my desk. Would you take a look at it?'" Hedge recalls. "I shook the filter out and looked at some samples on [microscope] slides. I was absolutely astonished to find samples full of what looked like glass fibers."

Intrigued, Hedge began reading up on mineral fibers. He learned that in the 1960s—when homes were built using fiberglass in the linings of ductwork—residents complained of health problems similar to today's SBS. He also discovered a number of building practices introduced in the 1970s that might be implicated in illnesses, such as the use of fiberglass in broad ceiling spaces or insulation placed inside the ventilation system where mineral fibers can shred and rain down on employees. "Inhaling [fibers] is like swallowing a . . . javelin," Hedge says. "If you swallow them end-ways, they can get quite far. The fiber pieces are three to eight microns in diameter and up to 30 microns long. They can cause fiber damage to epithelial cells of your eyes, nose, and throat." Hedge also believes fibers cause skin irritation and other symptoms.

Hedge says many researchers, steeped in the study of microbes or VOCs, have yet to seriously pursue the mineral fiber–illness relationship. However, researchers in England are working on similar studies, and Hedge is planning further studies on fibers.

Regulation Unlikely

At least for the time being, enforced regulations on workplace air quality appear unlikely. The closest policy makers have come is a 1994 proposal by OSHA that addressed a wide range of pollutants, including tobacco smoke. The proposed legislation called for employers to implement and maintain controls for many known pollutants. The proposal also asked employers to develop indoor air quality compliance plans and do inspections to make sure those plans work. While many indoor air researchers and activists supported the OSHA proposal, even more building owners, managers, and employers opposed it. "In our period of public comment we received over 115,000 comments," says Debra Janes, a health scientist and project manager at OSHA. "It's hard to find anyone who wants to take responsibility [for indoor air pollution]. And nobody wants to be cited over something they have no control over. Say there's a wet photocopier with solvents that are leaking. The building manager will say, 'That's not related to the building design. Why should we be responsible?'" Given the blast of negative responses, Janes says, it will take OSHA "a while" to review the responses received during the comment period.

The EPA continues to emphasize voluntary building standards to prevent indoor air pollutants. "We think there are incentives for doing it voluntarily," says Elissa Feldman, deputy director of the EPA's indoor air division. "Some real estate markets have rentable office space that's overflowing. [Quality indoor air] is a niche that some building owners could use to their advantage. It's also true that indoor air costs increasingly are associated with liability. In a big lawsuit, [the victim] can go after everybody from the architect to the general contractor and everybody along the way. Plus, getting a reputation as a sick building is really death to a marketable property."

The only way to tighten indoor air regulation and improve patients' diagnoses is to amass a broad collection of studies on poorly understood pollutants, researchers say. However, says Koren, "We are experiencing dwinding funding for this important health issue. There is a great deal of research that has only begun and that needs to be pursued vigorously to improve our understanding of the risks associated with the indoor air environment. And that is our number one goal."

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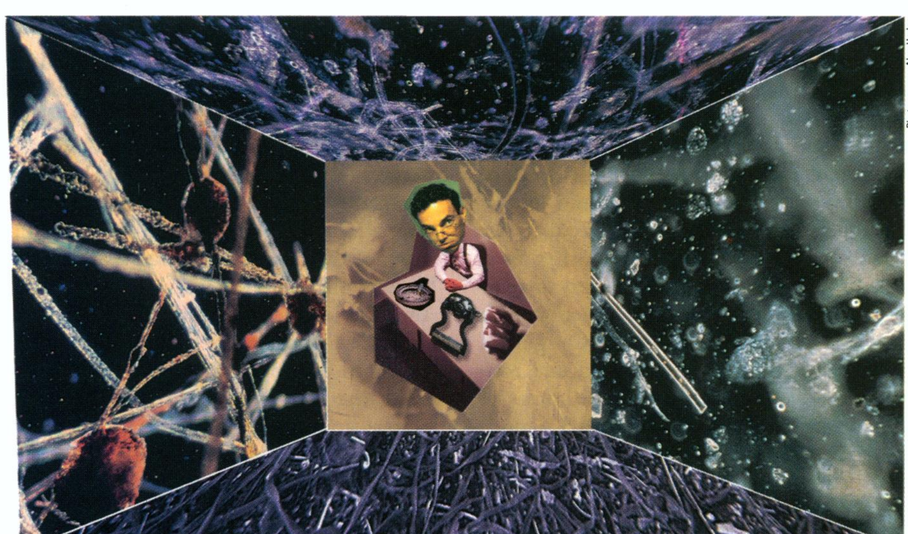

Photo source: Alan Hedge

Contaminated cubicles? Office dust particles contain a variety of mineral and synthetic fibers, which when inhaled deliver both mechanical and chemical irritants to the body.